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LV-11-C031

Measured Levels of Hospital Noise Before, During, and After Renovation of a Hospital Wing, and a Survey of Resulting Patient Perception

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ABSTRACT

Acoustic conditions in hospitals can negatively influence a patient's physical and psychological health. This paper reports on noise levels measured before, during, and after renovation of a hospital wing in an Omaha, Nebraska, facility that regularly receives unsatisfactory noise scores on patient satisfaction surveys. Sound pressure levels were logged every 10 seconds over four-day periods in three different locations: at the nurses' station, in the hallway, and in a nearby patient's room. The resulting data have been analyzed in terms of A-weighted equivalent sound levels (L_{Aeq}) as well as various exceedance levels (L_n). Results indicate that sound levels did not change much due to the renovation, due to a reduction in the scope of the renovation after the start of this project. The noise levels measured did regularly exceed currently recommended guidelines for hospital noise, though. A concurrent subjective survey on patient perception of hospital noise was conducted in the hospital wing during and after the renovation. Results from that survey show that patients in this hospital wing were most concerned with noise that originates from within their room, often linked to medical equipment or their roommate. The heating, ventilation, and air-conditioning systems ranked quite low among noise sources of concern at this facility. Based on the survey results, it does not seem that adding absorptive materials to the hallway or nearby nurses' stations would reduce noise from the sources considered most bothersome by the patients in this case study.

INTRODUCTION

Noise in hospitals has become a topic of growing concern in recent years, since it is often cited as a major complaint by patients in hospitals (Busch-Vishniac et al 2005). Busch-Vishniac et al (2005) reported that noise levels in hospitals have been increasing steadily since 1960, with current background noise levels averaging 72 dBA during the day and 60 dBA at night. These values are much higher than the guidelines set by the World Health Organization (1999), which recommend that the A-weighted equivalent sound levels (L_{Aeq}) in hospital rooms not exceed 35 dBA during the day and 30 dBA at night.

Unfortunately, research over the past 45 years has found that noisy conditions in hospitals lead to many non-auditory effects on patients and staff (Christensen 2005, Ryherd et al 2008). In particular, patient well-being is negatively impacted through sleep deprivation caused by noise disturbances (Topf et al 1996, Freedman et al 1999, Parthasarathy and Tobin 2004). Higher noise levels also increase patient stress levels, all of which can lead to increased amounts of pain medication, lengths of hospital stay, and wound healing times (McCarthy et al 1991). Minckley (1968) reported that higher levels of noise in a surgical recovery room were linked to a higher percentage of patients receiving pain medication; however, the data was only collected over five random work days. Another study found that cataract patients who experienced higher levels of noise

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due to the presence of nearby construction tended to require longer hospital stays, although the actual sound levels were not measured (Fife and Rappaport 1976). Other investigations have shown that higher levels of noise reduced the speed of wound healing in rats (Wysocki 1996); no definitive findings have been made regarding human wound healing, though.

In addition to affecting patient health, acoustical conditions in a hospital have also been correlated to patient perception of the quality of care received. A study by Hagerman et al (2005) placed patients in an intensive coronary care unit which either had ceiling tiles that produced a quality or poor acoustical environment. Those in the quality acoustic environment responded in subjective surveys that they were more satisfied with their care, and these patients also saw less re-hospitalization rates.

At a hospital in Omaha, Nebraska, responses from Press-Ganey Patient Satisfaction Surveys regularly indicate that noise in their hospital is an aspect about which patients express great dissatisfaction. Consequently, baseline noise level measurements were made by the authors in four similar wings at the hospital which had different material treatments (Wiese et al 2009). Results showed that acoustical material treatment such as absorptive ceiling tile and carpet did lower the ambient noise level (or the low-end) by just perceptible amounts; however, the peak levels (or high-end) did not vary greatly except in the neonatal intensive care unit (NICU), where other environmental controls have been instituted. In the NICU, the lighting levels are much dimmer than in other wings; also there are visual alarms that indicate if the noise level exceeds a certain amount. It is the authors' belief that both the ambient and the peak noise levels need to be addressed to improve the acoustical environment in hospitals. Lowering ambient levels through using more acoustically absorptive materials may reduce the overall stress caused by the environment, while reducing peak levels through other environmental or behavioral modifications may improve the likelihood that patients experience long restorative periods without noise interruption. Note that noise from the heating, ventilation and air-conditioning system was not an obvious cause of concern in these cases.

Subsequent to these findings, the hospital planned a renovation of one wing with the goal of incorporating both material and environmental changes to reduce the impact of noise on patient well-being. More absorptive materials were to be installed, as well as visual alarms and dimmed lighting at night. This paper reports on the objective and subjective data gathered before, during, and after the renovation. Objective measurements of the sound levels in that wing have been taken, before, during, and after the renovations were completed, while subjective data regarding patient perception were gathered only during and after the renovations, due to delays in receiving approval of the study from the hospital's Institutional Review Board.

Other researchers have found that implementing assorted material, environmental and/or behavioral changes can impact measured sound levels or patient perception (Webber 1984, Kahn et al 1998). MacLeod et al (2005) documented that adding absorptive materials to the hallway of a cancer unit at Johns Hopkins Hospital lowered sound levels and improved patient satisfaction; only 17 patients submitted the short five-question survey, though. Another study reported the results of a behavioral modification program in an intensive care unit, in which staff members were educated about the importance of sleep, and non-disturbance periods were implemented from 1-3 PM and 12-5 AM (Monsen et al 2005). Nursing staff were asked to document sleep disturbance factors for nine patients over a period of two weeks before and two weeks after the behavioral modification program, while sound levels were also recorded. Findings indicate that the intervention did reduce the number of sleep disturbance factors, as well as lower noise levels in some measure. However, patients were not polled for their own impressions.

Taylor-Ford et al (2008) measured sound levels and gathered noise perception data from both patients and staff, before and after a noise reduction program that included staff education about noise, the use of a visual alarm, and other minor physical alterations to the unit. These particular interventions did not yield statistically significant changes in overall sound levels, but patients and employees reported fewer disturbances after the interventions. Overman Dube et al (2008) conducted a similar study, surveying 30 patients before and after an intervention that included education of and behavioral modifications by the staff (e.g. soft voices, closing doors, limiting overhead paging) and assorted environmental changes (e.g. dimming lights). While the measured noise level readings increased 4 dB from pre-intervention to post-intervention, the perception of bothersome noise decreased as reported by both patients and staff. Evidence from another investigation highlights that changing staff behavior through noise awareness and education programs can reduce peak noise levels significantly but not

ambient levels (Richardson et al 2009). The findings from these investigations all support the hypothesis that reducing peak levels through environmental or behavioral interventions may have a greater impact on patient perception, more so than reducing ambient levels. Results from Stanchina et al (2005) further suggest that reducing the relative range between peak levels and ambient ones may be more important than only reducing absolute peak levels, since a smaller difference between peak and ambient levels reduced the number of sleep disruptions experienced by patients. More research is needed, however, to determine the upper limit for how much the ambient level may be raised before becoming a problem itself.

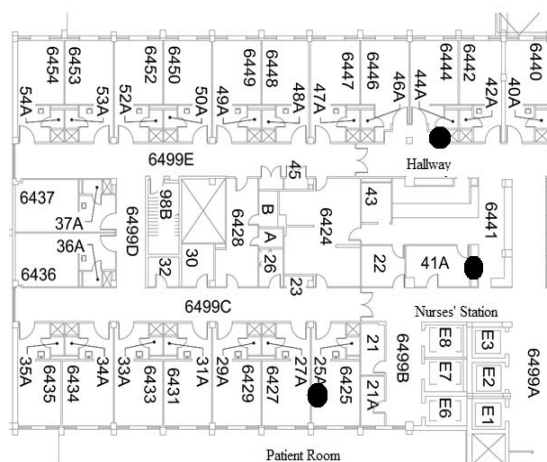
The project presented in the current paper includes more detailed acoustic measurements and a longer time period over which data on patient perception was accumulated than in many of the previous studies. Exceedance levels (L_n) are calculated in addition to L_{Aeq} ; specifically, L_{10} is the sound level exceeded 10% of the time, giving an approximate range of peak noise levels, while L_{90} is the sound level exceeded 90% of the time, giving an approximate range of ambient noise levels. Unfortunately, the material and environmental changes that were originally planned to the hospital ward under study were not fully implemented, which limited the significance of this project's findings regarding the benefit of the intervention. The data gathered from the patient surveys, however, remain useful towards understanding what type of interventions may have the most notable impact on the noise sources of greatest concern in this facility, as discussed below.

RESEARCH METHODOLOGY

Experimental Procedures

The hospital wing being investigated includes twenty double occupancy patient rooms along its outside corridor, with a centralized nurses' station and storage areas in the center (Figure 1). The flooring materials are hard linoleum in the hallway and patient rooms, and carpet in the nurses' station. Standard absorptive acoustical ceiling tile are found in the hallway and nurses' station, while the patient rooms have hard drywall ceilings. The walls of all the spaces are painted drywall.

Sound level measurements were made with calibrated Larson Davis 824 sound level meters at three time periods: before (December 2009), during (March 2010), and after (June 2010) renovations to the wing. Three meters were used, one at each of the following locations marked in Figure 1: the nurses' station, a patient room, and the hallway. The meters logged data on sound levels and frequency spectra every 10 seconds continuously over a four-day work week from Monday through Thursday, simultaneously at all three locations.



rooms in this wing appeared to have similar acoustic characteristics to the one in which sound level measurements were taken). The survey gathered data on age, gender, hearing impairment, and sensitivity to noise, as well as responses regarding how disturbed the subjects were by noise during the day and night, what noise sources were most bothersome, how difficult it was to hear spoken information, and how easily they overheard others discuss private patient information. The nursing staff assigned to this wing assisted with distributing and collecting the surveys from eligible subjects upon their being discharged from the hospital. Due to delayed approval of the subjective portion of the study by the hospital's Institutional Review Board, the survey was only distributed during and after renovations, which spanned a period of three and a half months.

Patient Discharge Survey on Noise During Hospital Stay

*Please answer the following questions by marking the appropriate box(es) or filling in the blanks, and return the completed survey in the envelope provided to the nursing staff.
Thank you for your participation!*

Gender: Male ☐ Female ☐ Discharge Date: _____

Age: 19-25 ☐ 26-30 ☐ 31-35 ☐ 36-40 ☐ 41-45 ☐ 46-50 ☐ 51-55 ☐ 56-60 ☐ 61-65 ☐ 66-70 ☐ 71-75 ☐ 76 and up ☐

Do you (the patient) have any known hearing impairments? Yes ☐ No ☐

1a. How often were you awakened at night by sounds during your hospital stay, other than by a nurse for a required activity?
Never ☐ Rarely ☐ Sometimes ☐ Often ☐

1b. How annoyed were you at being awakened?
Did not wake ☐ Not at all ☐ Slightly ☐ Moderately ☐ Extremely ☐

2a. How often was your rest during the day disturbed by sounds during your hospital stay, other than by a nurse for a required activity?
Never ☐ Rarely ☐ Sometimes ☐ Often ☐

2b. How annoyed were you at being disturbed?
Did not wake ☐ Not at all ☐ Slightly ☐ Moderately ☐ Extremely ☐

3. Please rank the top 5 sources of noises that disturbed you during your hospital stay, with 1 being the most bothersome.

| | |
|---|---|
| Medical equipment <u>in</u> patient room <input type="checkbox"/> | Medical equipment <u>outside</u> of patient room <input type="checkbox"/> |
| Alarms <u>in</u> patient room <input type="checkbox"/> | Alarms <u>outside</u> of patient room <input type="checkbox"/> |
| Talking <u>in</u> patient room <input type="checkbox"/> | Talking <u>outside</u> of patient room <input type="checkbox"/> |
| Rolling carts in hallway <input type="checkbox"/> | Office equipment outside of patient room <input type="checkbox"/> |
| TVs <input type="checkbox"/> Other entertainment devices <input type="checkbox"/> | Heating, ventilation, air-conditioning <input type="checkbox"/> |
| Other (please describe): _____ <input type="checkbox"/> | |

4a. Did you ever have a hard time hearing or understanding the comments from staff because of noise?
Yes ☐ No ☐

4b. If so, how often?
Never ☐ Rarely ☐ Sometimes ☐ Often ☐

5a. Were you able to hear other patients, guests or staff discussing private information that did not pertain to you in the areas around you? Yes ☐ No ☐

5b. If so, how often?
Never ☐ Rarely ☐ Sometimes ☐ Often ☐

6. Would you describe yourself as being sensitive to noise? Yes ☐ No ☐

7. Please make any additional comments regarding noise during your hospital stay on the back of this form.

IRB APPROVED

VALID UNTIL 2-18-15

Figure 2 The survey instrument used to gather data on patient perception of hospital noise.

Data Analysis

The sound level meter measurements were analyzed within Microsoft Excel to calculate L_{Aeq} , L_{10} and L_{90} over a variety of time periods: the overall values over each 4-day measurement period; the daily daytime values between the hours of 7 AM to 10 PM; and the daily nighttime values between the hours of 10 PM to 7 AM. Spectral data were also examined.

With regards to the patient survey, responses to each survey question were coded numerically and input into the statistical analysis software SPSS (v18) for further analysis. Because many of the responses did not demonstrate normal or symmetric distributions, non-parametric tests were used to analyze the data, including Chi-square tests, Kruskal-Wallis tests,

and Mann-Whitney U tests (Field 2005, Pallant 2007). The accepted level of significance for all analyses was $p < 0.05$. The statistical tests were used to determine if there was any statistically significant difference between the responses gathered during the renovation and those gathered after the renovation. Also the statistical analyses indicated which responses to the different questions were significantly correlated (e.g. sensitivity to noise and degree of annoyance caused by hospital noise).

RESULTS

Objective Measurements

A plot of the measured sound levels (overall L_{Aeq} , average daytime L_{Aeq} , and average nighttime L_{Aeq}) can be found in Figure 3. The values range between 51 and 63 dBA, much higher than WHO guidelines for day or night. When comparing the levels at each location taken before, during, and after the renovation, very small differences are found, on the order of 3 dB or a just noticeable difference of sound level. Because the scope of the renovation was reduced to include only painting the walls and upgrading the television sets in patient rooms, the small variations between the sound levels measured at these three time periods are expected. The spectral data also changed very little through the renovation process.

Comparisons of L_{10} and L_{90} values are presented in Figure 4. The measured L_{10} and L_{90} values do not vary much across the phases of the renovation, with L_{10} generally remaining around 57-60 dBA while the L_{90} values are about 15 dB less at around 42-47 dBA. Even the measured L_{90} 'ambient' values are clearly higher than the given guidelines by WHO.

Subjective Survey Results

The purpose of the survey was to measure people's perceptions of the noise in the hospital and determine what the most bothersome noise sources were in the during renovation and after renovation time periods. The total number of discharged patients from the hospital wing who were eligible to participate in the survey was 210. Of the 158 patients who responded (75% response rate), 108 were at the hospital during the renovation and 50 were there after the renovation period.

Only the statistical results considered of most interest are presented below. A more thorough presentation and discussion of all the statistical tests that were run may be found in Wiese (2010).

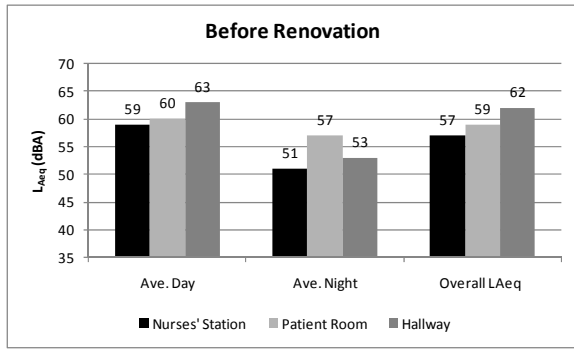
Participants spanned across all the age ranges listed in the survey, with most participants (88 out of 158) being between 40 and 60 years of age. Statistical analyses show that age was not statistically related to any of the responses received on other questions. Regarding gender, females were the majority of the responders (99 females, 56 males, 3 not responding). As with the variable age, gender was not statistically related to any of the responses received on other questions.

Responses to the annoyance questions (#1 and #2 in Figure 2) show that over 80% of the patients were not annoyed at all or only slightly annoyed by the noise in the daytime for either time period of the survey; this number decreased slightly at night to 72%. Very few patients (9%) of the total group indicated having a hard time hearing what was said to them (Question #4). A greater concern was being able to overhear other private conversations (Question #5). Of those surveyed, 33% of respondents indicated that they could overhear private conversations. Indeed some of the patients noted in the comment section that they were able to hear the discussions between other patients and their care providers which prompted concerns of their own privacy.

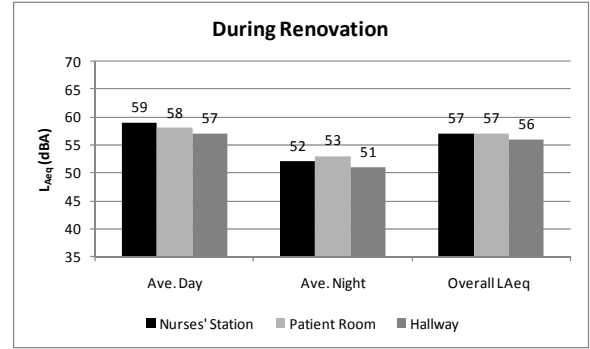
24% of the participants reported themselves as being sensitive to noise (Question #6). As found in other studies (Topf 1985, 1989), these persons tended to be the ones that responded that they were more severely annoyed by noise in the hospital during the night ($p < 0.001$) and day ($p = 0.001$).

Chi-square analyses were run to determine if any of the responses to the survey questions reviewed above changed significantly from during the renovation to after the renovation. All of these tests were found to be not statistically significant, as expected due to the limited renovation that was done.

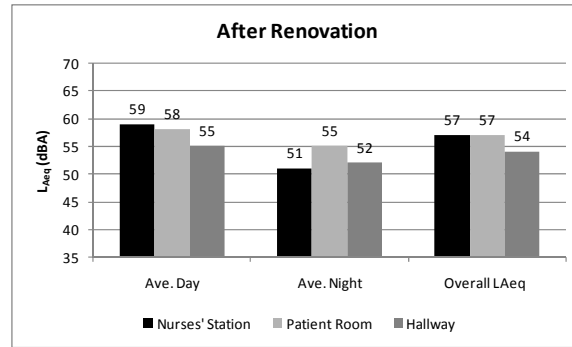
Lastly, let us present the results from Question #3 which asked subjects to mark the noise sources they considered most bothersome. A few respondents ranked the sources as requested from one through five, while others just marked all the noise



(a)

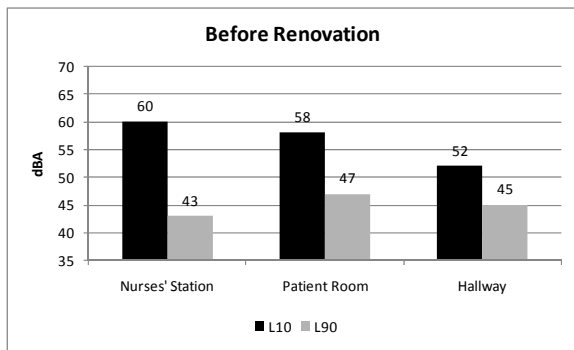


(b)

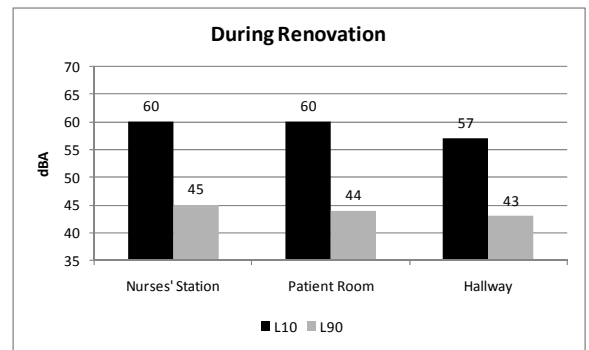


(c)

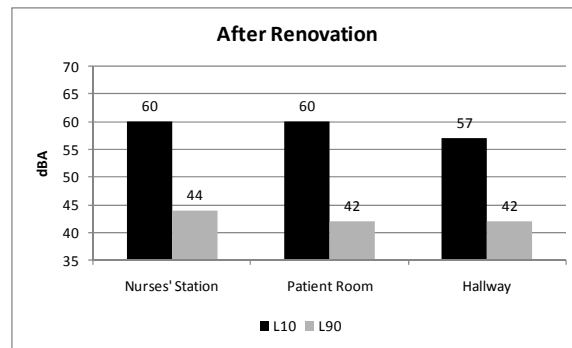
Figure 3 Comparisons of L_{Aeq} values for all three locations (a) before, (b) during, and (c) after renovations.



(a)



(b)



(c)

Figure 4 Comparisons of L_{10} and L_{90} values for all three locations (a) before, (b) during, and (c) after renovations.

sources that bothered them with check marks. Some marked several items with number one or two, etc., and did not clearly indicate which their top choice was. Therefore, to use the results of this question, every item checked by a participant was counted one time in calculating the total count; then this total count was used to establish the ranking order for the assorted noise sources. The sources that received the most marks in the combined data set (both during and after renovation) were as follows: *Alarms in Patient Room*, *Medical Equipment in Patient Room*, *Rolling Carts in Hallway*, *Talking in Patient Room*, and *Talking Outside Patient Room*. *Heating, Ventilation and Air-conditioning (HVAC)* noise was ranked number 11 of 12 source categories, receiving just 2% of the total number of responses. These results are applicable for this particular facility, but may not be the same for other hospitals which may have quieter medical equipment or noisier HVAC systems.

Chi-square analyses were run to determine if there were any differences regarding bothersome noise sources between the during renovation and after renovation time periods. Only two categories were found to have statistically changed: *TV Noise* evidenced a statistically significant increase in its ratings from during to after renovation ($p=0.002$) and *Talking in Patient Room* showed a significant decrease from during to after renovation ($p=0.02$). Apparently the addition of new flat-screen television sets in the patient rooms did result in some changes in patient behavior which impacted noise perception.

To summarize, the most bothersome noise sources in this facility as indicated by patient responses were from the equipment needed for the patient's care and from the behavior of other people such as roommates having visitors, or staff treating the roommates. The authors surmise that most of the noise sources that received the highest number of marks in this study would not be impacted by adding absorptive materials in areas outside of the patient room, since these sources (e.g. alarms and speech) tend to contribute to peak noise levels. They would more likely be impacted by environmental or behavioral interventions, rather than material ones, as reviewed in the previous literature.

CONCLUSIONS

Sound level measurements of hospital noise have been collected in a hospital before, during, and after a renovation of a hospital wing, and a survey on patient perception afterward was analyzed. Unfortunately due to a reduction in the scope of the renovation, the sound level meter measurements show fairly consistent values between the three time periods; the actual changes that were made in the hospital wing were not able to produce significant decreases in the noise levels, either ambient or peak. All of the acquired A-weighted equivalent sound levels were higher than the recommended WHO guidelines by at least 20 dB. Since many studies have shown that sound levels in hospitals rarely meet these guidelines, it is suggested that they should be adjusted to be acceptable values for patient comfort and health while being more realistically achievable.

The survey on patient perception of hospital noise reveals that a large percentage of respondents did not appear to be appreciably annoyed with the noise levels in this hospital wing, either during the day (80%) or night (72%), even though noise has been repeatedly cited as a problem for the hospital based on their Press Ganey Patient Satisfaction Survey results. A significant relationship was found between those who did express greater levels of annoyance and those who also rated themselves as being sensitive to noise.

The top five noise sources compiled from the combined data set (both during and after renovation) were found to be: *Alarms in Patient Room*, *Medical Equipment in Patient Room*, *Rolling Carts in Hallway*, *Talking in Patient Room*, and *Talking Outside Patient Room*. The noise from *Heating, Ventilation and Air-conditioning* equipment received the second lowest number of marks in this facility; such rankings may not be the same at other hospitals which exhibit different conditions, though. Only *TV Noise* and *Talking in Patient Room* changed significantly from during the renovation to after the renovation, which is easily attributed to the addition of new audiovisual equipment in the patient rooms.

Overall, the renovations in this study were not considerable enough to alter patients' perceptions of hospital noise. Still, responses from the survey do provide insight as to the leading concerns for patients regarding noise in this hospital. Many patients wrote in the comment section about the difficulties of having a roommate and of having others hear their private medical conversations. Recommendations for improving the impact of the most bothersome noise sources at this facility include the following: have private patient rooms; install visual alarms to monitor speaking levels; have earphones available for use with TV or other entertainment devices; use consultation rooms to discuss private medical information with patients; and/or distribute earplugs to patients which has been found at least to improve sleep satisfaction by Scotto et al (2009).

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